FAO Fisheries Technical Paper No. 70
(Distribution restricted)

FRs/T70
Fishery Management

LIBRARY
Pacific Islands Fisheries Science Center
2570 Dole St.
Honolulu, Hawaii 96822-2396

THE CONCEPT OF THE MAXIMUM SUSTAINABLE YIELD AND FISHERY MANAGEMENT

by

J.A. Gulland

Fish Stock Evaluation Branch

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1968

FAO FISHERIES TECHNICAL PAPER

This is one of a series of Technical Papers (see inside front cover) dealing with aspects of the work of FAO Fishery Resources and Exploitation Division, including the review of pertinent information on particular topics, to meet requests for assistance, for presentation to technical and scientific meetings, etc. Extra copies can be obtained by application to:

Biological Data Section
Fishery Resources and Exploitation Division
FAO, Rome, Italy

(Papers issued since January 1966)

FIb/T41	Manual of methods for fish stock assessment. Part III. Selectivity of fishing gear	January 1966
FRm/T60	Establishment, structure, functions and activities of international fisheries bodies - III - Regional Fisheries Advisory Commission for the South West Atlantic (CARPAS)	February 1966
FRm/T62	Observations from international oceanographic expeditions relevant to tuna ecology	April 1966
FRi/T15 Rev. 1 Ad. 1	A list of inland fishery workers in Europe	April 1966
	Liste des spécialistes des questions de pêches dans les eaux intérieures en Europe	April 1966
FIb/T51 Suppl. 1	Manual of methods for fish stock assessment - Part IV - Marking	
	Manuel sur les méthodes d'évaluation des stocks ichtyologiques - Partie IV - Le marquage	
	Manual de métodos para la evaluación de los stocks de peces - Parte IV - Marcado	April 1966
FRs/T63	Report on the effects on whale stocks of pelagic operations in the Antartic during the 1965/66 season and on the present status of those stocks	June 1966
FI/T64	International fishery bodies - Paper presented at the first session of the Committee on Fisheries - Rome, 13-18 June 1966	
	Organismes internationaux des pêches - Documents soumis à la première session du Comité des pêches - Rome, 13-18 juin 1966	
	Organismos pesqueros internacionales - Documentos presentados al primer período de sesiones del Comité de Pesca - Roma, 13-18 junio 1966	August 1966
FRs/T38 Rev. 1	Manual of methods for fish stock assessment - Part II - Tables of yield functions	
	Manuel sur les méthodes d'évaluation des stocks ichthyologiques - Partie II - Tables des fonctions de rendement	
	Manual de métodos para la evaluación de los stocks de peces - Parte II - Tablas de funciones de rendimiento	September 1966
FRs/T19.1 Suppl. 3	World List of periodicals for aquatic sciences and fisheries	
	Répertoire mondial de périodiques concernant les sciences aquatiques et la pêche	
	Lista mundial de publicaciones periódicas referentes a las ciencias acuáticas y a la pesca	November 1966
FRs/T66	The echo sounder and its use for fishermen	April 1967
FRm/T71	Fishermen and the weather	February 1968
FRm/T70	The concept of the maximum sustainable yield and fishery management	February 1968

FAO Fisheries Technical Paper No. 70
(Distribution restricted)

FRs/T70
Fishery Management

THE CONCEPT OF THE MAXIMUM SUSTAINABLE YIELD AND FISHERY MANAGEMENT

by

J.A. Gulland
Chief, Fish Stock Evaluation Branch

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, March 1968

PREPARATION OF THIS PAPER

This paper reports some results of studies being carried out by the Fish Stock Evaluation Branch and other units of FAO on the general problems of fishery management and the rational uses of the living resources of the sea. Another report recently published is "The Management of Fishery Resources" which appeared in the 1967 issue of "The State of Food and Agriculture", and was reprinted in World Food Problems No. 7. Another version of this report, prepared by J.A. Gulland and J.E. Carroz, will appear in "Advances in Marine Biology" Vol.6.

Distribution :

FAO Department of Fisheries
FAO Regional Fisheries Officers
Members of COFI
Fishery Commissioners
Selected scientists
Selector 5

"Current Bibliography" entry :

Gulland, J.A. (1968) 13-6M131
FAO Fish.tech.Pap., (70):13 p.
The concept of the maximum sustainable yield and fishery management

Population management. Regulatory measures. Biological management. Economical management.

CONTENTS

Introduction 1

Biological aspects: a single stock 1

Stock fluctuations 4

Several stocks 4

Economics 6

Discussion 11

References 12

THE CONCEPT OF THE MAXIMUM SUSTAINABLE YIELD AND FISHERY MANAGEMENT

by

J.A. Gulland

Introduction

The concept of the "maximum sustainable yield" has a long history in fisheries literature, particularly when the results of research into the population dynamics of fish stocks have been applied to the problems of managing the fisheries. Some of the early criticisms of the concept were biological; for instance, Beverton and Holt (1957) showed that, at least for the model used, when the size of first capture could be continuously altered to the optimum value (e.g. through increasing the size of trawl meshes) the resultant curve of catch against fishing effort - the 'eumetric' curve - had no maximum.

Recently there have been economic criticisms that the point of maximum physical yield is not the most desirable objective of management, because a slightly smaller yield could be obtained with considerably less fishing, and the attainment of this level of fishing, giving the "maximum net economic yield" should be the objective of fishery management, (e.g. Christy and Scott 1965).

Although the concept of "maximum sustainable yield" has had these criticisms it still provides the most concise, and at least on the surface, simplest definition of the objective of fisheries management, and one that can command quite general agreement. It is in fact embodied in at least one convention (ICNAF, in the form of "maximum sustained catch"). The present note examines the extent to which the concept can be maintained in the face of criticisms of its biological and economic aspects, and if it cannot be maintained, what simple statement of the aims of fishery management can be put in its place.

Biological aspects: a single stock

The simplest situation in fisheries management is of a stock of a single species of fish, which does not compete with, eat, or form the food of a stock of any other commercially exploited species. The dynamics of such a stock are most simply, if not completely realistically, described by the classic laws of population growth (Volterra 1931), the 'sigmoid' curve of Graham (1939) - which states that at each level of population abundance there is a certain unique natural rate of increase. If the catch taken is equal to this natural increase, the population will be sustained at that level. Transformed into a curve of catch against fishing effort this relation in its simplest mathematical form gives a parabola (Schaefer 1954, 1957). The maximum in this curve precisely defines the maximum sustained yield.

More complex theories take into account not only the total biomass of the population, and the weight caught, but also the sizes and ages of fish concerned. These show that if the size of the smallest fish caught is adjusted to give the greatest catch at the existing level of fishing effort, and is increased with increased fishing effort, then the total

catch will continue to increase (if only very slightly) with increasing fishing (Beverton and Holt 1957). With certain exceptions, such as the blue whale (Balaenoptera musculus) stocks in the Antarctic (Chapman 1964), where the very close relations between adult stock and total number of young produced makes the assumptions of the model inherently more probable, there are few if any clear examples of observed data of an actual fishery fitting the simple, parabolic yield curve of Schaefer over most of its range. Equally there are few examples of fisheries for which the average yield has been observed over a wide range of fishing effort, and for which the resulting empirical yield/effort curve has the shape predicted by the eumetric curve of Beverton and Holt. This is due principally to the shortage of data - there are few fisheries for which there have been several periods of stable fishing, each at different levels of fishing effort.

Such empirical data that does exist for a wide range of fishing effort suggests that the relation between mean catch per unit effort (stock abundance) and effort is not the straight line required by the simple Schaefer theory, but rather a curve concave upwards (Gulland 1961). The most recent data for the yellowfin tuna of the eastern Pacific also suggests that the catch per unit effort at high levels of effort is greater than is suggested by a straight line, though this may be due to the different sizes of fish caught by the purse seines, which have been the main gear used at the higher effort levels while in the earlier years of the fishery, at lower effort levels, the main method of fishing was using live bait.

Such curved catch per effort/effort relations may still result in catch/effort curves which have maxima, but these maxima will occur at higher levels of effort, and the curve each side of the maxima will be much flatter; thus the position of the maximum of any curve will be less distinct, and more difficult to determine with any precision (see Figure 1). These difficulties are illustrated in the figure as uncertainties in fitting an empirical line to data of catch and effort, suitably transformed. When more complex, and more realistic models are used the uncertainties will take other forms, such as the degree to which population parameters, such as growth, and especially recruitment, vary with stock abundance. Of these the stock/recruitment relationship presents more difficulties; even when the recruitment has declined so much as to bring about the collapse of the fishery it may be still not certain whether the recruitment failure is in any way due to fishing; c.f. the Californian sardine (Murphy 1966) or the herring in the southern North Sea (ICES 1967). In terms of the catch/effort curve all these doubts result in a similar uncertainty as to whether the curve has a pronounced maximum, declining fairly rapidly at higher levels of effort, or has a relatively flat top (e.g. the theoretical curve for herring, ICES 1966a).

There are, therefore, theoretical arguments as to whether the maximum exists, or whether the eumetric yield-per-recruit model holds good and there is no maximum. But these are less formidable drawbacks to the application of the maximum sustainable yield as an objective of management than the difficulty in practice of determining the position of this maximum. When giving advice to a commission or other regulating body about the state of a stock of fish, and the effect of fishing on it, there may be considerable uncertainty among scientists as to the position of the maximum relative to the present level of effort, even when it is clear that fishing is having a substantial effect. That is, it may be difficult for scientists to give definite advice to a commission or other regulatory body on whether it is necessary to increase, or decrease the fishing effort in order to attain the maximum sustainable yield. However, there may be less uncertainty regarding the relative heights of the maximum (if any), and the present catches on the vertical scale of Figure 1, so that it may be quite clear that the present level of effort gives an average catch which is, say, within 10% of mean catch at the maximum. Thus, confident advice may be given to the Commission to the effect that increasing the fishing effort will result in no appreciable increase in total catch, and perhaps a decrease (cf. ICES and Liaison Committee advice to NEAFC on cod at Iceland, ICES 1966b, also ICNAF 1964).

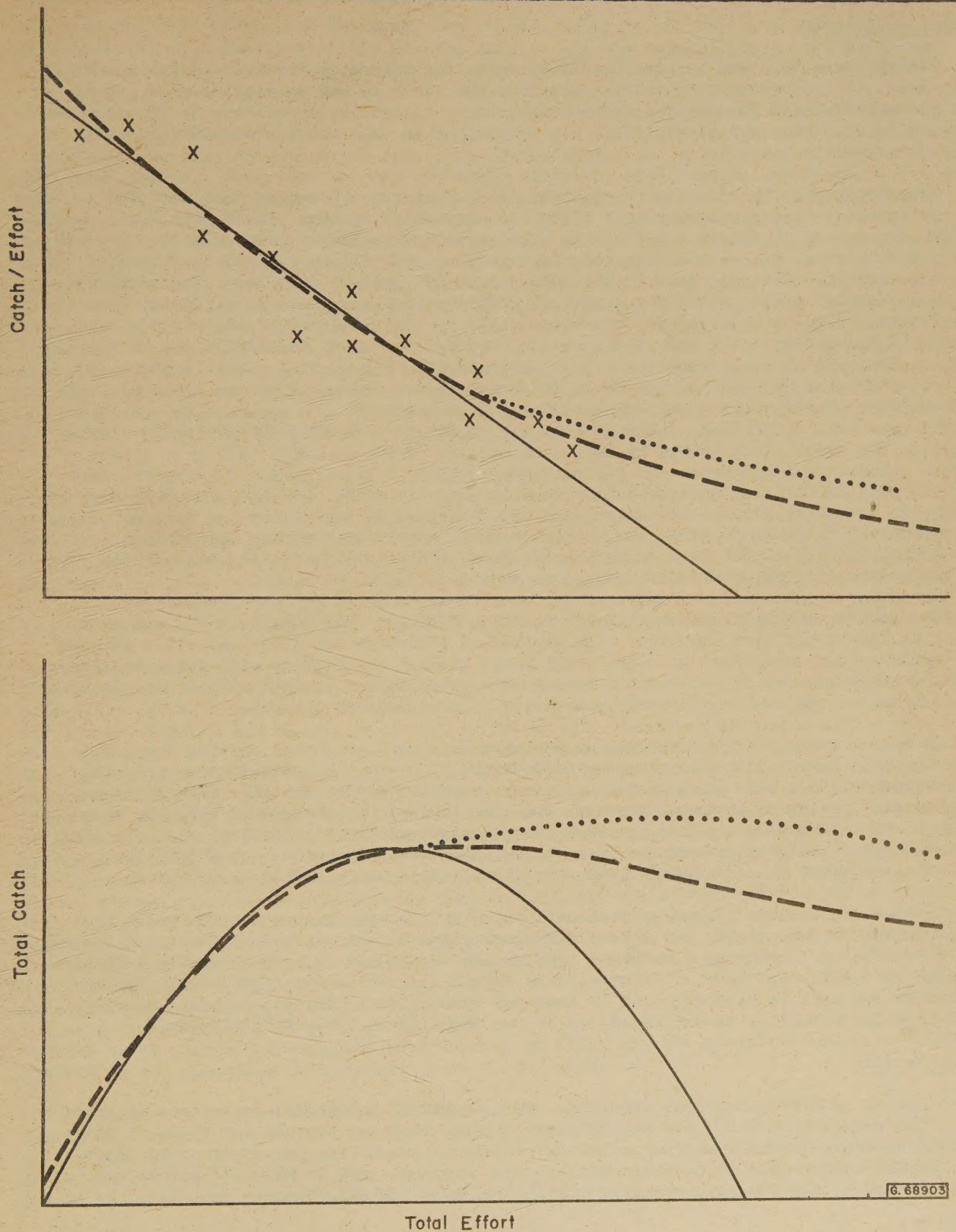

Fig. 1 - Possible relations between effort and catch/effort; and corresponding relations between effort and catch.

Stock fluctuations

Though there thus may be some degree of certainty regarding the average catch with a given level of effort, this is often not so for the catch in any particular year. Many fish stocks fluctuate for reasons quite independent of fishing, especially due to changes in recruitment. For such stocks it is not meaningful to talk about a sustainable yield in the strictest sense.

Thus Hennemuth (1967) estimated for the haddock stocks of Georges Bank that the average catch at that level of effort (7,000 standard fishing days) which gave the maximum average catch, to be 45,000 tons. This gives a reasonable measure of the productivity of the area, and may be compared, for example, with the corresponding estimates for other stocks. However, even if the effort is maintained at this level for a period, the "sustainable" yield in any one year during this period may be quite different from 45,000 tons. This is true whether the sustainable yield is defined as the catch which results in the stock at the end of the year being the same as at the beginning, or as the catch which would be taken with the effort maintained at the optimum level (7,000 days). Thus in 1964/5 the outstanding 1962 and 1963 year-classes recruited to the fishery; this attracted considerable extra effort, especially from the USSR. As a result the catches in 1965 rose to 155,000 tons, compared with the 70,000 tons in 1964 (ICNAF 1967b). Despite this the stock (as measured by the catch per day of US trawlers) fell only slightly (5.6 to 5.1 tons/day compared with 4.4 tons/day in 1963, Graham 1967). Clearly if the catch in 1965 had been considerably less than it was, but still well above 45,000 tons, say 80,000 tons, the stock would have increased. Equally if the effort had been maintained since 1964 at 7,000 days (the estimated total effort in 1965 was 27,600 days - US 9,400 days, USSR 14,600 days, others 3,600 days, ICNAF 1967b), the catches in 1965 and still more in 1966, would have been much more than 45,000 tons.

Conversely, the later year-classes - in 1964, 1965 and 1966 (Graham 1967) are weak, and it is inevitable that the stock will decline in 1968/9 as the 1963 year-class becomes old, whatever the catch that is taken (with heavy fishing the decline will occur earlier). However, the figure of 45,000 tons is useful as a guide to the productivity of the Georges Bank haddock stocks, and may be compared with similar estimates for other stocks.

In such a fishery the term "maximum sustainable yield" is a poor one for the yield which would be taken with the optimum effort, since it may not be sustainable, and will be exceeded in years when good year-classes are present. A more suitable term would be the potential yield, or average potential yield to include the concept of variable year-classes. In this sense, one can consider the potential yield of individual year-classes; the potential yield from an average year-class of Georges Bank haddock is 45,000 tons, while the potential yield from the 1962 year-class was probably around 100,000 tons.

In such fluctuating fisheries, the estimation of a single figure for the value of the potential or sustainable yield from the stock gives a poor measure of the catch that should be taken in any particular year. The proper management is best basically defined in terms of the desired size of first capture and fishing mortality coefficient, though the latter may well be best attained in practice by regulating the total catch, determined annually according to the abundance of the stock (Anon 1966, ICNAF 1967a).

Several stocks

No stock of fish exists in isolation. Most stocks of commercial importance interact with other valuable stocks; one may feed on another, they may compete for food, or they may both be taken by the same gear. The catch that is taken from one stock will, therefore, depend on the fishing on the other stocks. A simple case is when the stocks are fully mixed, and the fishing mortality must be the same for all. Then as calculated by

Beverton and Holt (1957) for the North Sea plaice, haddock, and cod, a combined yield can be calculated as a function of the fishing effort, and the selectivity of the gear, e.g. mesh size. This requires that the yields of the different stocks are expressed in the same units; clearly weight can be used, but it is unrealistic to treat a ton of cod as equal to a ton of plaice, when there is an average value difference in European markets of about 1:2 (ICES 1966c). To use total value as was done by Beverton and Holt, however, introduces economic factors which lose much of the attractive objectivity of the "maximum sustained yield". These factors may be highly variable, both between countries, and from year to year for a single country. As an extreme example, the price of soles in the Netherlands is at present several times that of plaice, but in the early nineteenth century, plaice were highly valued, but soles were considered worthless (Van den Ende 1849, fide de Veen 1967). Another interesting feature is that the forms of the yield curves become more complex; thus for probable values of fishing effort the yield/mesh size curve has two maxima - one around 100 mm corresponding to the optimum for the small fish (haddock), and another around 200 mm corresponding to the optimum for cod and plaice (when the catches of haddock would be negligible). The second of these is, for the larger values of fishing effort, the higher. This larger mesh size might give the greatest yield for the North Sea demersal stocks as a whole but be unacceptable to the fishermen who are less interested in cod and plaice than in smaller fish such as sole (e.g. Belgium and the Netherlands) or haddock and whiting (e.g. Scotland).

More often the fishery can be directed predominantly to one species or another; sometimes to the extent that the catches of one species can be considered as only incidental to the catches of the preferred species. Thus, the US tuna fishery in the eastern tropical Pacific has been mainly directed towards yellowfin tuna; so much so that the effort may be greater than that necessary to take the maximum sustained yield of yellowfin, while skipjack are under-exploited (IATTC 1966). It is therefore desirable that the effort on yellowfin be limited, but the greatest catch of tuna from the area can only be achieved by an increase in total fishing, provided that most of this is directed towards skipjack.

When more than one stock is exploited in the same area, several gears may be used. Then a species that is the major interest to fishermen using one gear may be caught incidentally by fishermen using another gear. Thus in the North Sea, haddock, and particularly small haddock are caught by trawlers fishing with small meshed trawls for herring (Sahrhage 1958). There is little doubt that the total haddock catch would be increased if this by-catch of haddock was eliminated (ICES 1960), but this is not possible without severe interference with the herring fishing, and thus reducing the yield of herring. Thus, with present fishing techniques the greatest catch of herring and the greatest catch of haddock cannot be taken at the same time; the greatest total yield may be calculated by combining the haddock and herring catches in terms of weight (which will underestimate the value of the haddock fishery) or of value (which may be subject to considerable variations, as the price of herring depends very much on the use to which the catch is put - fish meal, or direct human consumption). Probably such calculations would show that the greatest total yield would be obtained by maximising the herring catch, and accepting as inevitable the destruction of small haddock, and the resultant reduction of catch to the haddock fishermen (predominantly Scots) though it is possible that in terms of total value, herring trawling should be restricted, when the loss in catches would fall on the herring trawlers (from Germany, Poland, etc.). The very recent development of purse-seining for herring in the North Sea suggests that herring trawling and the resultant losses to haddock fishing is not necessary to maximise the herring catch.

Interaction between fisheries may occur even when each fishery takes only one species, due to biological factors. Thus in the area between Norway and the Shetlands the stock of dogfish (Squalus acanthias) eat considerable quantities of herring estimated as 29,500 tons (Holden 1965) as well as, on occasion, damaging the drift-nets of herring fishermen. Though there is some doubt about the precise quantity eaten, and the effect of this on the

herring fisheries, it is clear that a reduction in the dogfish stock would result in a benefit to the herring fisheries. It is reasonably clear, too, that the greatest physical yield from the combined stocks - assuming for simplification that dogfish eat only herring, though in fact they eat many other species, including several exploited commercially - would be taken by eliminating dogfish and catching only herring.

This is a special case of the general rule that the greatest weight will be caught by exploiting the lower trophic levels. This conclusion is obvious on general biological considerations, in view of the 85-90% loss in production in going from one trophic level to the next. However, it contrasts with the objectives of most of the present international commissions which are either specifically directed at the conservation of certain valuable species - tuna, halibut, salmon - which belong to high trophic levels, or have paid their main attention to such predator species (e.g. cod). Thus regulations aimed at maintaining the maximum sustainable yield of halibut off the west coast of North America may have resulted in reducing the total catch in the area. Regulations on the type of gear that may be used to catch halibut have probably delayed the development of fishing on some of the other demersal species. These fisheries have now developed but the presence of a large stock of halibut, which are predators on many of the other species, has probably tended to reduce the stocks and catches of the latter. This of course is no criticism of the work of the International Halibut Commission within its terms of reference, which are to act for the benefit of the halibut fishery.

Economics

A major criticism of the simple concept of the maximum sustained yield as an objective of management has come from economists. They have pointed out that as at the maximum the curve of catch against fishing effort is flat, the marginal increase in catch achieved in increasing the fishing effort from just below the maximum up to the maximum is very small. That is, expressing both catch and fishing effort in monetary terms, a very small increase in value of the catch will require a much greater increase in the cost of capture. Clearly, it is not reasonable to spend $1,000 to get an extra $10 worth of fish, and it is therefore better (in some sense) to fish at rather less than the level of effort giving the maximum sustainable yield.

Economists have, therefore, suggested (e.g. Christy and Scott 1965, p.221f) that the objective should be to obtain the greatest net economic yield from the fishery. This corresponds to the point A in Figure 2. This, adapted from the yield/effort curves of Figure 1, shows the value of the catch plotted against the cost of capture. To a first approximation cost is proportional to fishing effort, and value of the catch to the weight caught, so that the shape of the curve in Figure 2 is the same as that in Figure 1. Minor differences from proportionality will not change the shape much. In Figure 2, the line OB represents equal costs and value, so that the point B on the curve represents an equilibrium position at which, in the absence of other factors, the fishery would tend to settle. The point A is, therefore, the point where the tangent to the curve is parallel to the line OB. If costs and values were constant, then this point would provide an uniquely definable objective and optimum position of fishery management. Costs and values do not however remain constant so that the optimum amount of fishery would increase each time costs decreased, or unit value increased, and vice versa. More seriously, at any one time, costs and values are not likely to be the same for all countries, so that on the criterion of maximum net economic return each country might determine a different optimum position. If the differences in costs and values are large, the practical possibilities in achieving agreed international management are small, since it would be to the advantage of the country with exceptionally low costs or high values to continue unregulated fishery until competing countries can no longer afford to fish. In fact, if several countries are fishing on the same stock of fish, though the absolute value of their unit costs or values may be different, the ratio of costs to value (which determines the position of the

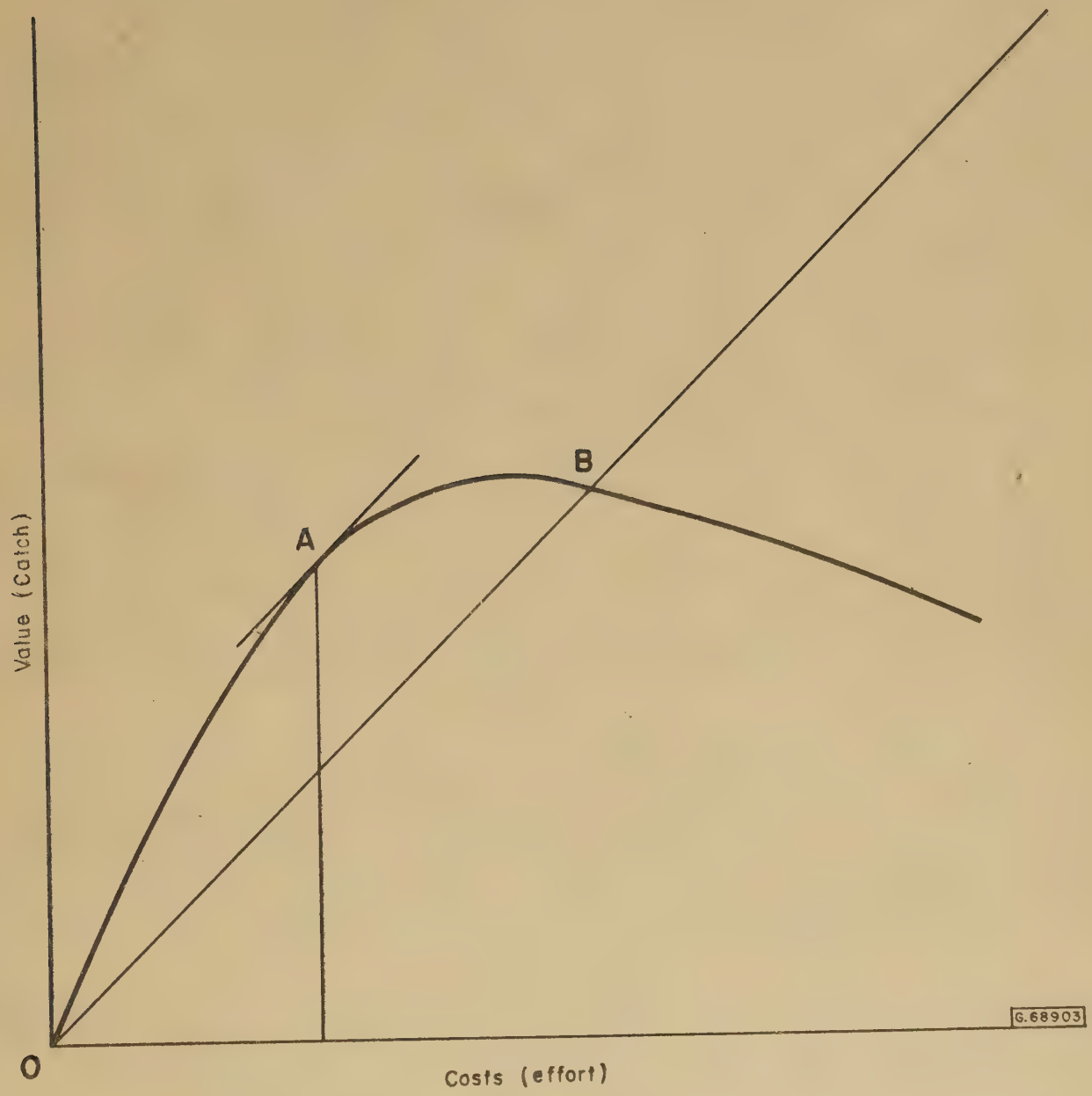

Fig. 2 - Relation between the total cost of fishing and the value of the catch, corresponding to a typical catch/effort relation shown in Fig. 1.

economic optimum) is unlikely to differ much from unity. A fishery will not continue long if the costs are much greater than the value of the catch, and it is an unusually profitable fishery in which the costs are less than half the value. In Figure 2 it may be seen that a difference of say 20% either way in the slope of the tangent makes no great difference to its position. Thus, in most important situations the 'optimum' positions (giving the maximum net economic yield) for different countries will be quite close - usually much closer to each other than any one is to the position of the maximum sustained yield. Certainly the optimum positions will all occur at levels of effort less than that giving the maximum physical yield. It might also be argued that it is in the interest of the international community taken as a whole for a particular resource to be harvested by that country which can do it most effectively - at the least cost per unit fishing mortality, or at the greatest value per unit weight caught. This would enable a unique optimum (the fishery mortality giving the maximum net economic return) to be defined at any particular moment, but would not prevent this optimum changing from time to time, as fishing techniques improve, or the price of fish changes.

Many countries are less interested in specific individual fisheries - either maximising catch or economic return from that fishery - than in the yield to them of the ocean's fish resources as a whole - as total weight of fish, net economic return or any other form. Even individual fishermen are, to an increasing extent, interested actually or potentially, in more than one stock. The modern long-range fleets of factory and mother ships, freezer/trawlers, etc. switch quickly from stock to stock across great distances as the availability of fish changes. Even in Peru, where the biggest single species fishery in the world supports the major part of the industry, individual vessels can and have been converted from purse seining for anchoveta to trawling for demersal species. For these fishermen, and others, the management of the individual stocks on the basis of the economic return is likely to give results to the fishery on all stocks more in accordance with the total objective - whether this is maximum total catch, maximum economic return or something else - than will management of the individual stocks on the basis of the maximum sustained yield from that stock. This statement will probably hold true unless all the stocks which are potentially available to the fishermen are already too heavily exploited.

To illustrate this, consider the case of two stocks of fish, one of which is heavily exploited - the effort is greater than that giving the maximum yield and the other is lightly exploited. For simplicity, it will be assumed that the two stocks are exploited by the same fleet of vessels, but are sufficiently separated, either geographically or in behaviour, so that a unit of fishing effort can be directed only to one species at a time. The two curves of catch against fishing effort are shown in upper and lower parts of Figure 3. The catch and effort have been expressed, in the same scale, as total value and costs. The equilibrium position for the two stocks, in the absence of regulation, A_1,B_1, will be where the lines of equal cost and value cut the catch/effort curves.

Since the first stock A is "overfished" by most if not all definitions of the term, some reduction of effort is desirable. The effort might be restricted to give the maximum catch from stock A, i.e. the point A_2. This involves a reduction in effort from OC_1 to OC_2, and if the total costs of all fishing operations remain constant the effort on stock B can be increased from OD_1 to OD_2. Similarly, if stock A is to be managed to give the greatest net economic return from that stock the optimum point is A_3, with the effort reduced to OC_3; correspondingly the effort on stock B can be increased, within the same total, to OD_3.

The fishing effort and catches corresponding to these possibilities are given in Table 1 (in arbitrary units).

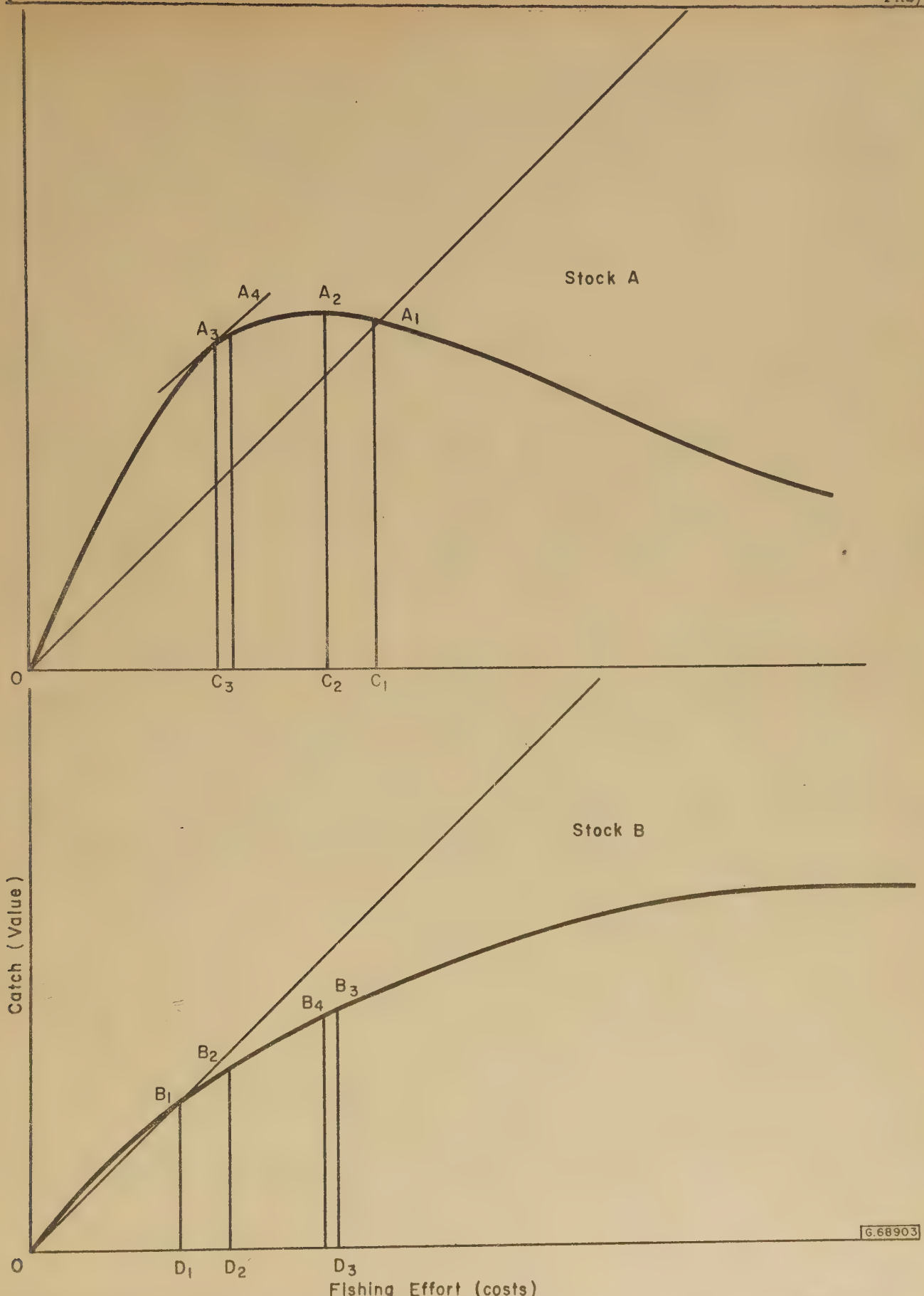

Fig. 3 - The effect on the combined yield from two stocks if excess fishing on one stock is diverted to the other. For a fuller explanation see text.

Table 1

	Effort (Costs)			Catch (Value)		
	Stock A	Stock B	Total	Stock A	Stock B	Total
1. Unregulated	70	30	100	70	30	100
2. A at maximum catch	60	40	100	72	36	108
3. A at maximum net economic yield	38	62	100	66	48	114
4. Maximum total catch	41	59	100	68	47	115

This table shows that the increase in catch, from the unregulated level achieved by taking the maximum catch from stock A, is, for this particular situation, only just more than half the increase achieved by taking the maximum net economic yield from stock A. In this latter situation, rather too much effort is diverted to stock B, and the greatest total yield (for the given level of total effort) is achieved when the slopes of the two curves are equal, i.e. the marginal yields per unit effort, in the sense of Gulland (in preparation), from the stocks are equal. This corresponds to the points A_4, B_4 in the figure and the fourth line in the table.

This example has, for clarity of exposition, been taken from a situation which shows a fairly marked improvement in total catch by not attempting to maximise the catch from the overfished stock. In other situations, the difference may be less great. But just as the greatest net economic yield will always be achieved by a fishing effort less, if only slightly less, than that giving the maximum catch, so it will always be possible to increase the total catch by diverting a little effort to the less heavily fished stocks as compared with taking exactly the maximum catch from the overfished stock.

While the above calculations show what the greatest combined yield could be from the two stocks, there are likely to be difficulties in actually achieving this. The marginal yield per unit effort (the slope of the tangent to the curve) is the same for the two stocks, but the actual catch per unit effort - the return to the individual fisherman - (the slope of the line joining the origin to the point on the curve) is considerably greater for stock A than stock B (about twice as great as drawn in the figure). Given the choice fishermen would much prefer to fish on stock A than on stock B. If the stocks and the fishing operations are under single ownership and control, then the desired distribution of fishing between the stocks may be achieved, but otherwise more or less complex regulations may be needed. For instance a large licence fee might be charged for fishing stock A; the right to land species A might be subject to also landing a certain percentage of species B, etc. Thus the regulation for fishing for tuna in the eastern tropical Pacific closes fishing for yellowfin after a certain date, subject to a maximum of 15% being allowed when fishing for other species. This allowance will presumably encourage fishing for other species - principally skipjack - or yellowfin in other areas during the closed season, though it might be argued that the existence of the closed season, whose dates are fixed with regard to the catch during the open season, will discourage fishing for any species other than yellowfin during the open season. The precise effect of such a regulation on skipjack catches - and hence to a large extent on total tuna catches - is therefore not easy to predict, and will depend on small local

factors - the relative prices of the two species, their relative seasonal and geographical distribution, etc. What is fairly certain is that regulations which are effective in obtaining the maximum yield of yellowfin are unlikely to produce the greatest combined yield of all tuna - too much effort will be wasted in catching the last few tons of yellowfin. The same will be true of any other regulation aimed at getting the maximum yield from one stock when the same fishermen can also fish some other still lightly exploited stock.

Discussion

The concept of the maximum sustainable yield was developed from simple biological models of stocks of single species of fish. The apparent simplicity of this concept has made it attractive as the defined objective of fisheries management. This simplicity is deceptive, and the concept is only useful and realistic in the most simple conditions. An alternative concept, of the maximum net economic yield has been proposed, but this too is not universally applicable. Fishery management does not, however, need to have a single, clearly defined objective, other than a general objective of improving the fisheries. No body charged with the management of an existing fishery will expect to arrive at the optimum position, even if one can be defined, at one step. Rather, at any one time it will seek such acceptable measures as will lend to some general benefit to the fishery. Ultimately a series of such steps will, unless their magnitude becomes vanishingly small, result in the fishery arriving at its optimum condition. However, as Professor Crutchfield has pointed out, there is usually a constraint on these measures; not only must the result to the fishery as a whole be beneficial, but in many situations there must be no losers. This constraint, which corresponds to the present practical and political realities in many fishery commissions, can result in a fishery remaining in a less than optimum condition. For instance, considering only one species, one group of fishermen may fish inshore on the nursery grounds, while another, perhaps much larger group, fish off-shore on the large fish. The total yield might be increased by stopping fishing on the nursery grounds, but this would be unacceptable to the inshore fishermen. This problem would exist however the objectives of management were defined. One solution lies in greater authority of the management body (commissions, etc.) so that for example the losing groups can be compensated during some transition period, from money obtained by licences fees from the groups that gain. How the bodies concerned with management of fisheri s on the high seas can be provided with such additional authority - by new forms of international agreements, international ownership, or extension of national authority - is one of the most urgent problems facing those concerned with international fisheries.

References

Beverton, R.J.H. and S.J. Holt, On the dynamics of exploited fish populations.
1957 Fishery Invest., Lond.(2), 19:533 p.

Chapman, D.G., Special committee of three scientists. Rep.int.Commn.Whal.,
1964 14:40-92

Christy, F.T. and A.D. Scott, The commonwealth in ocean fisheries. Baltimore,
1965 Md., John Hopkins Press, 281 p.

de Veen, J.F., On the phenomenon of soles (solea solea L.) swimming at the
1967 surface. J.Cons.perm.int.Explor.Mer., 31(2):207-36

Ende, W.P. Van den, Eenige bijzonderheden betrekkelijk de schol. Arnhem, Versl.
1849 Werk-Zaamk.Veren.Berord.onld.Ichtyol, Vol.2:147-64

Graham, M., The sigmoid curve and the overfishing problem. Rapp.P.-v.Réun.Cons.perm.
1939 int.Explor.Mer, 110:15-20

Graham, H.W., U.S. research report 1966. ICNAF Annual meeting. Research
1967 document, 22

Gulland, J.A., Fishing and the stocks of fish at Iceland. Fishery Invest.,
1961 Lond.(2), 23(4):52

_____, The concept of the marginal yield from exploited fish stocks.
(in press) J.Cons.perm.int.Explor.Mer., 32(2)

Hennemuth, R.C., Georges Bank haddock: biological aspects. Appendix to report
1967 on the biological and economic effects of conservation action.
ICNAF Annual meeting 1967, Committee Doc.67/19

Holden, M.J., The food intake of the spurdog, Squalus acanthias L. ICES,
1965 Annual Meeting 1965, Near Northern Seas Committee, Doc.89(mimeo)

ICES, Report of the Ad Hoc committee. J.Cons.perm.int.Explor.Mer., 23:7-37
1957

_____, International Fisheries Convention of 1946. Committee on Mesh
1960 Difficulties. Report of the scientific sub-committee. Rapp.P.-v.
Réun.Cons.perm.int.Explor.Mer, 151:39 p.

_____, Report of the assessment group on herring and herring fisheries
1966a in the North-eastern Atlantic. Liaison committee report for 1965.
Co-op.Res.Rep.int.Coun.Explor.Sea,(B), Annex 2

_____, Report of the North-western working group. ICES, Gadoid Fish
1966b Committee, Doc.G1(mimeo)

_____, Bulletin statist.Pêch.marit., Copenh., 50
1966c

_____, Liaison committee report for 1967. Co-op.Res.Rep.int.Coun.
1967 Explor.Sea,(B)

ICNAF, Report of the Assessment sub-Committee. Red Bk int.Commn NW.Atlant.
1964 Fish.(2), pp.61-75

ICNAF, Note by the United Kingdom commissioners on the regulation of fishing
1966 effort. ICNAF Annual Meeting 1966, Committee Doc. 66/17

_____, Report of the Working Group on the Biological and Economic effects
1967a of conservation action. ICNAF Annual Meeting 1967, Committee Doc. 67/19

_____, Report of the Assessment sub-Committee. Red Bk int.Commn NW.Atlant.
1967b Fish.(1), pp.28-52

Murphy, G.L., Population biology of the Pacific sardine (Sardinops caernlea).
1966 Proc.Calif.Acad.Sci., 34(11):1-84

Sahrhage, D., Untersuchungen über die vernichtung untermassiger Schellfisch durch
1958 die deutsche Heringsschleppnetz-fischerei in der Nordsee. Ber.Dt.wiss.
Kommn Meeresforsch., 15:105-31

Schaefer, M.B., Some aspects of the dynamics of populations important to the
1954 management of the commercial marine fisheries. Bull.Inter.Am.trop.
Tuna Commn 1(2):27-56

_____, A study of the dynamics of yellowfin tuna in the eastern tropical
1957 Ocean. Bull.Inter.Am.trop.Tuna Commn 2(6):245-85

Volterra, V., Leçons sur la théorie mathématique de la lutte pour la vie. Paris.
1931

DOCUMENTS OF THE FISHERY RESOURCES AND EXPLOITATION DIVISION OF FAO DEPARTMENT OF FISHERIES

Documents which are not official FAO publications are issued in several series. They are given a restricted distribution and this fact should be indicated if they are cited. Most of them are prepared as working papers for meetings, or are summaries of information for use of member governments, organizations, and specialists concerned.

DOCUMENTS DE LA DIVISION DES RESSOURCES ET DE L'EXPLOITATION DES PECHES DU DEPARTEMENT DES PECHES DE LA FAO

Des documents qui ne figurent pas parmi les publications officielles de la FAO sont publiés dans diverses séries. Ils font seulement l'objet d'une distribution restreinte, aussi convient-il de le préciser lorsque ces documents sont cités. Il s'agit le plus souvent de documents de travail préparés pour des réunions, ou de résumés d'information à l'intention des gouvernements des pays membres, ainsi que des organisations et spécialistes intéressés. Ces séries sont les suivantes:

DOCUMENTOS DE LA DIRECCION DE RECURSOS PESQUEROS Y EXPLOTACION DEL DEPARTAMENTO DE PESCA DE LA FAO

Esta Subdirección publica varias series de documentos que no pueden considerarse como publicaciones oficiales de la FAO. Todos ellos tienen distribución limitada, circunstancia que debe indicarse en el caso de ser citados. La mayoría de los títulos que figuran en dichas series son documentos de trabajo preparados para reuniones o resúmenes de información destinados a los estados miembros, organizaciones y especialistas interesados.

FAO Fisheries Report **FR /R (No.)**
FAO Fisheries Circular **FR /C (No.)**
FAO Fisheries Synopsis **FR /S (No.)**

Special groups of synopses are identified by symbols followed by classification numbers based on indexed code of "Current Bibliography":

SAST Data concerning certain species and fish stocks.

MAST Information on methods and subjects.

OT Oceanographic data.

IT Limnological data.
and

CART Information concerning fisheries and resources of certain countries and regions (FID/S).

Des catégories spéciales de synopses sont identifiées à l'aide de symboles suivis des chiffres de classification basés sur le code d'indexation de la « Current Bibliography »:

SAST Données sur certaines espèces et populations de poissons.

MAST Renseignements sur des méthodes et des sujets.

OT Données océanographiques.

IT Données limnologiques.
et

CART Renseignements sur les pêcheries et les ressources de certains pays et régions (FID/S).

Grupos especiales de sinopsis se distinguen con las siglas siguientes, seguidas por números de clasificación que se basan en las claves de los índices de la "Current Bibliography".

SAST Datos relativos a ciertas especies y poblaciones.

MAST Sinopsis sobre métodos y materias.

OT Sinopsis sobre oceanografía.

IT Sinopsis sobre limnología.
y

CART Información sobre los recursos acuáticos vivos de algunos países y regiones (FID/S).

FAO Fisheries Technical Paper FR /T (No.)

Special groups of Technical Papers are identified by:

RE Indexed lists of experts and institutions drawn from Registers maintained by the Fishery Resources and Exploitation Division.

CB Lists of periodicals, special sections of "Current Bibliography for Aquatic Sciences and Fisheries", special bibliographies and papers concerning documentation problems.

MFS Provisional editions of "FAO Manuals in Fisheries Science".

Des catégories spéciales de documents techniques sont identifiées à l'aide des symboles suivants:

RE Listes indexées d'experts et institutions tirées des registres tenus à jour par la Division des ressources et de l'exploitation des pêches.

CB Listes de périodiques, des sections spéciales de la « Current Bibliography for Aquatic Sciences and Fisheries », des bibliographies particulières et des articles sur les problèmes de documentation.

MFS Editions provisories des « Manuels FAO de science halieutique ».

Grupos especiales de documentos técnicos se identifican por las siglas siguientes:

RE Listas índices de expertos y de instituciones tomadas de los registros que se llevan en la Dirección de Recursos Pesqueros y Explotación.

CB Listas de periódicos, secciones especiales de la "Current Bibliography for Aquatic Sciences and Fisheries", bibliografías especiales y trabajos relativos a los problemas de documentación.

MFS Ediciones provisionales de los "Manuales de la FAO de Ciencias Pesqueras".

Some documents also have another identification, if, for example, they have been contributed to a meeting for which papers have been numbered according to another system.

Certains documents portent parfois d'autres numéros d'identification, par exemple, s'ils ont été préparés pour une réunion dont les documents ont été marqués à l'aide d'un autre système.

Algunos documentos tienen también otra identificación si, por ejemplo, son contribuciones a una reunión cuyos documentos han sido marcados con arreglo a otros sistemas.

MI/7I323/I2.69/E/2/300